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(71) Applicant: **NORTHERN TELECOM LIMITED**
World Trade Center of Montreal, 380 St. Antoine Street West, 8th Floor
Montreal, Quebec H2Y 3Y4(CA)

(72) Inventor: **Hadjifotiou, Anagnostis**
137 The Maples
Harlow, Essex(GB)

(74) Representative: **Dupuy, Susan Mary et al**
Northern Telecom Europe Limited Patents and Licensing West Road
Harlow Essex CM20 2SH (GB)

(54) Optical communications systems.

(57) In an optical communications system including a transmitter (laser 1) and a receiver, with an optical amplifier (3) and an optical filter (4) therebetween, the position of the passband of the optical filter (4) is adjusted automatically in dependence on a received pilot carrier signal frequency transmitted with the data. This facilitates initial selection of transmitter laser (1) and avoids the need for transmitter laser frequency stabilisation. The optical filter acquires and tracks the optical carrier used by the transmitter

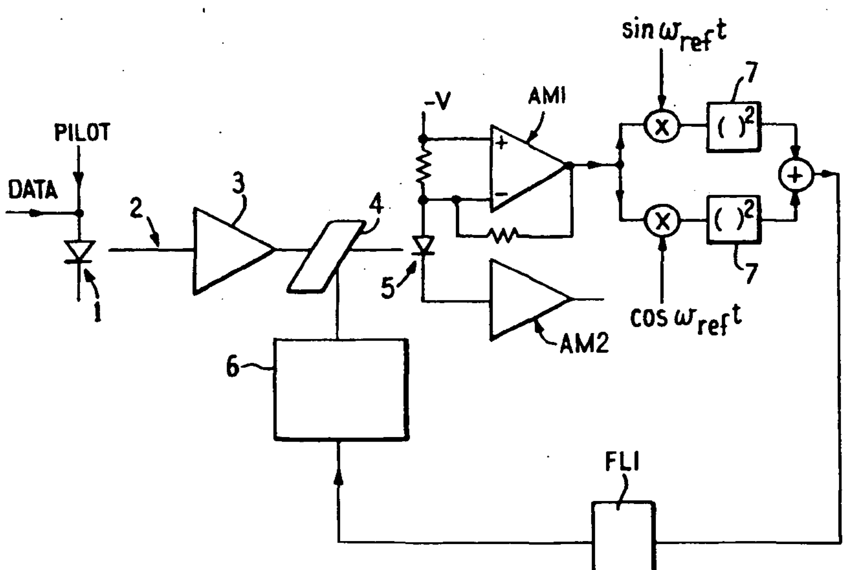

FIG.1

This invention relates to optical communications systems and in particular to optical communications systems including optical amplifiers.

Optical communications systems in which data is transmitted between transmitter and receiver terminals over optical links, in particular optical fibre links, may employ optical amplifiers comprised by semiconductor devices or erbium doped silica fibres, for example, in the optical links. The use of an optical amplifier enhances the sensitivity of the optical receiver at the receiver terminal. The degree of enhancement depends on the amount of optical filtering used between the optical amplifier (also known as an optical pre-amplifier) and the receiver. In principle, the narrower the filter, the higher the sensitivity enhancement. However, the use of narrow band optical filters has two disadvantages. The first is the requirements it imposes on the selection of the transmitter laser wavelength and the second is the requirement it imposes on the stability of the transmitted wavelength with time over the lifetime of the system.

The present invention aims to remove both of these restrictions.

According to the present invention there is provided an optical communications system comprising an optical transmitter and an optical receiver and including an optical amplifier and an optical filter arranged in series therebetween, data being transmitted by the transmitter to the receiver, and including means whereby an optical pilot carrier signal is added to the data to be transmitted and means whereby the position of the passband of the optical filter is adjusted in dependence on the received optical pilot carrier signal frequency such that the passband tracks variations in the transmitted frequency.

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 illustrates, schematically, a basic system which employs the present invention, and

Fig. 2 illustrates, schematically, part of another system which employs the present invention.

The basic optical communications system illustrated in Fig. 1 comprises an optical transmitter (laser 1), an optical link 2 including an optical pre amplifier 3 and an optical filter 4 in series, and a receiver including a photodetector 5. In order to overcome the disadvantages referred to above, an adaptive optical subsystem is provided which ensures that the optical filter 4 acquires and tracks an optical pilot carrier used by the optical transmitter. The construction and principle of operation of this subsystem will now be described.

The transmitter adds a pilot carrier or signal (pilot) to the data to be transmitted. The frequency of the pilot carrier is chosen to be below or above the frequency hand occupied by the data. The data and pilot signal are transmitted between the transmitter and the receiver and may be amplified by amplifiers (not shown) therebetween prior to reaching optical preamplifier 3. After passing through the optical filter 4, the pilot signal is detected differentially by the receiver including photodetector 5 and amplified by amplifier AM1. The received data are amplified by amplifier AM2, which is the low noise amplifier of the optical receiver. After AM1 the pilot signal is either filtered and rectified or, and as shown, it is mixed with a local reference frequency w_{ref} to be detected synchronously by the square law detectors 7. The advantage of synchronous detection over non-synchronous detection is the higher sensitivity of the former. After either of these operations the pilot signal is filtered by filter FL1 and applied to an optical filter controller 6 which can either be comprised by a computer or dedicated electronics. Filter FL1 filters out the high frequency signal components generated by the detection (synchronous or non-synchronous). The optical filter 4 is a fixed bandwidth optical filter. For example, a multilayer interference filter. With such a filter the position of the passband can be adjusted by adjusting the angle of incidence of the incoming radiation. The optical filter controller 6 uses the output of filter FL1 to generate a signal which changes the frequency (wavelength) of the maximum response of the optical filter 4 so that it coincides with that of the transmitted optical carrier signal. In this way the position of the passband of the optical filter 4 always coincides with the transmitted optical signal and the sensitivity of the receiver is maximised.

This apparatus can be used with an intensity modulated format or with any of the coherent modulation formats, such as frequency shift keying, phase shift keying or amplitude shift keying. Further it can be used with an optical preamplifier, as described above, and/or with optical line amplifiers (Fig. 2).

A more detailed description of some aspects of the invention will now be given with reference to Fig. 2, which relates to an optical line amplifier application. Input light is applied to optical amplifier 13 which is followed by optical filter 14, the optical output of which is transmitted on towards a distant receiver. The light required for the filter control is tapped off by means of fibre coupler 15 as illustrated but this is not the only possibility. The filter control arrangement of Fig. 2 is the same as illustrated in Fig. 1 and comprises a photodetector 16, detection means including sqare law detector 7 at the output of amplifier 18, a filter 19 and a computer or dedicated electronics comprising an optical filter controller 20.

Two phases of operation of the arrangements shown in Figs. 1 and 2 can be distinguished; carrier acquisition and carrier tracking. These will now be described with referenc to Fig. 2.

In the carrier acquisition phase, the peak of the passband response of the optical filter 14 does not coincide with the transmitted wavelength and the input to amplifier 18 is zero. Under these conditions the optical filter controller 20 initiates a search in the sense that the position of the passband of optical filter 14 is changed under control and the output of filter 19 continuously monitored. When the position of the passband of the optical filter 14 coincides with the transmitted carrier signal, the output from filter 19 increases and that signals to the controller 20 that the optical carrier is within the then passband of the optical filter 14. At this stage the acquisition phase is completed, searching stops and tracking commences. During the tracking phase any small changes in the carrier wavelength (frequency) are compensated by the controller 20 which, using the output of filter 19, commands the optical filter 14 to follow the changes in the carrier (pilot) wavelength.

In summary, a pilot carrier is added to the data and both are transmitted over an optical path. At the receiver after an optical preamplifier, or simply after a repeater amplifier, the pilot is detected and a control system driven by the detected pilot ensures that the position of the passband of an optical filter, between the preamplifier (or repeater amplifier) and an optical receiver, coincides with the transmitted optical carrier signal.

The use of a tracking filter arrangement as described above makes the selection of lasers for optical systems using optical amplifiers very easy and furthermore the transmitter does not require frequency stabilisation.

Claims

1. An optical communications system comprising an optical transmitter (1) and an optical receiver (5) and including an optical amplifier (3) and an optical filter (4) arranged in series therebetween, data being transmitted by the transmitter to the receiver, characterised by including means whereby an optical pilot carrier signal is added to the data to be transmitted and means (AM1, 7, FL1, 6) whereby the position of the passband of the optical filter (4) is adjusted in dependence on the received optical pilot carrier signal frequency such that the position of the passband tracks variations in the transmitted frequency.

2. A system as claimed in claim 1 characterised in that the optical amplifier (3) is a preamplifier of the receiver and including means whereby the received pilot carrier signal is detected differentially at the receiver (5) from the output of the optical filter (4), amplified, filtered to remove high frequency signal components generated by said detection and applied to a controller (6) for the optical filter, the controller serving to change the frequency of the maximum response of the optical filter so that it coincides with that of the transmitted optical pilot carrier signal.

3. A system as claimed in claim 1 characterised in that the optical amplifier is an optical line repeater amplifier (13) and including means whereby the pilot carrier signal at the output of the optical filter (14) is detected (16), amplified (18), filtered (19) to remove high frequency signal components generated by said detection and applied to a controller (20) for the optical filter, the controller serving to change the frequency of the maximum response of the optical filter (14) so that it coincides with that of the transmitted optical pilot carrier signal.

4. A system as claimed in claim 2 or claim 3 wherein the detected pilot carrier signal is filtered and rectified prior to said filtering.

5. A system as claimed in claim 2 or claim 3 wherein the detected pilot carrier signal is mixed with a local reference frequency prior to said filtering.

6. A system as claimed in any one of the preceding claims wherein the optical amplifier is a semiconductor device.

7. A system as claimed in any one of the preceding claims wherein the optical amplifier is an erbium doped silica fibre.

8. A system as claimed in any one of the preceding claims wherein the optical filter is a multilayer interference filter or another filter whose band pass position can be adjusted.

9. A system as claimed in claim 2 or claim 3 wherein the optical filter, detection means, amplifying means, filtering means and said controller comprise a tracking filter which serves automatically initially to acquire the carrier signal and then to track it.

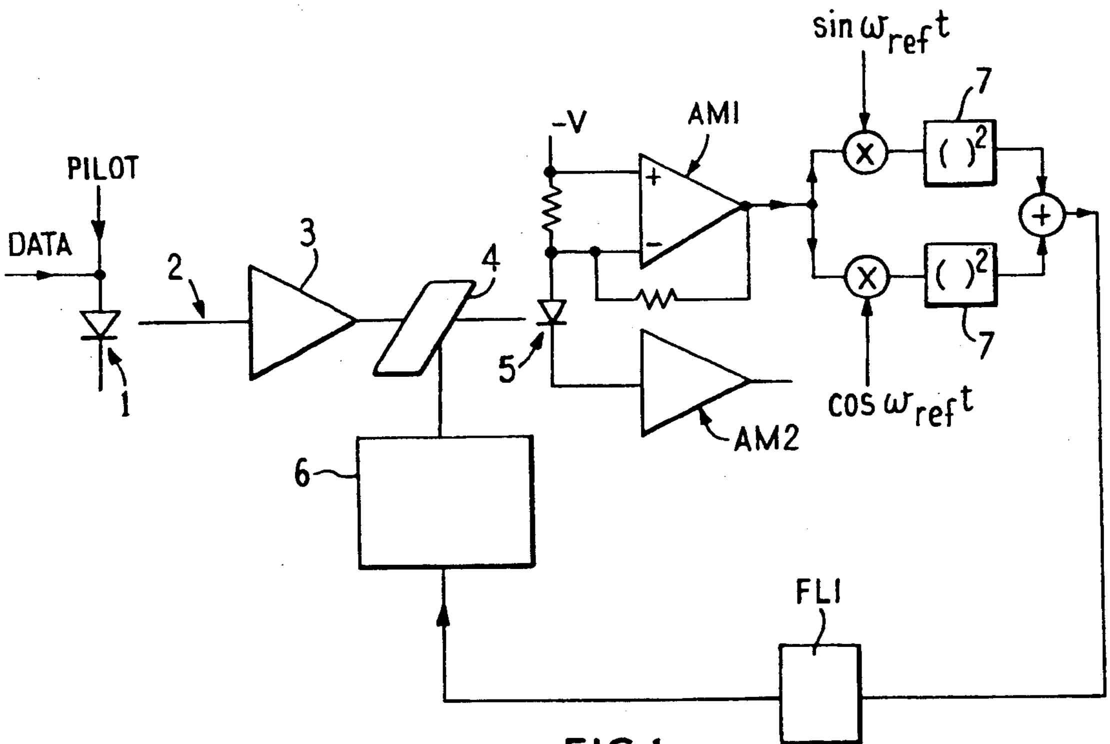
sin ω_{ref}t
7
-V
AMI
PILOT
DATA
3
2
4
5
1
6
AM2
cos ω_{ref}t
FL1

FIG.1

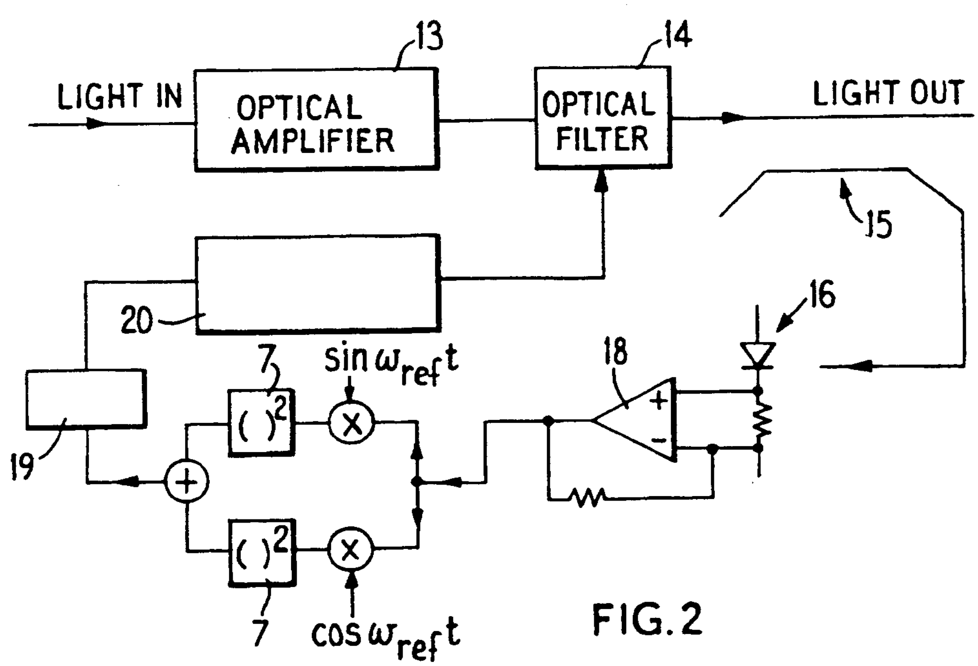
13
14
LIGHT IN
OPTICAL AMPLIFIER
OPTICAL FILTER
LIGHT OUT
15
16
20
7
sin ω_{ref}t
18
19
cos ω_{ref}t

FIG.2

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World Trade Center of Montreal, 380 St. Antoine Street West, 8th Floor
Montreal, Quebec H2Y 3Y4(CA)

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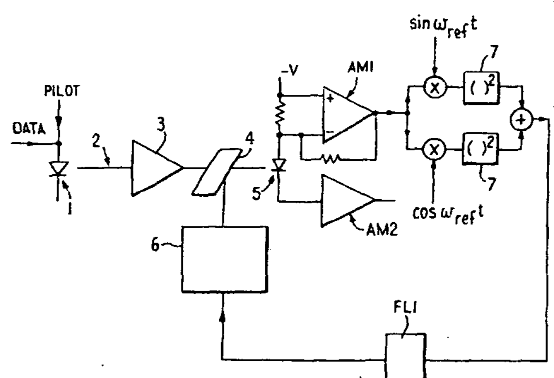

FIG. 1

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A	IEEE PHOTONICS TECHNOLOGY LETTERS vol. 2, no. 10, October 1990, NEW YORK US pages 753 - 755 R.C.STEELE ET AL 'High-Sensitivity FSK Signal Detection with an Erbium-Doped Fiber Preamplifier and Fabry-Perot Etalon Demodulation' * page 753, left column, paragraph 1 -paragraph 2; figure 1 * ---	1-3,7	H04B10/14
A	PATENT ABSTRACTS OF JAPAN vol. 5, no. 186 (E-84)(858) 25 November 1981 & JP-A-56 112 143 (TOKYO SHIBAURA DENKI) * abstract * ---	1,8,9	
A	DE-A-3 828 200 (J.HEIN ET AL) * abstract; figure 1 * ---	1,8,9	
A	IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE AND EXHIBITION , GLOBECOM 90 vol. 3, 2 December 1990, SAN DIEGO, CALIFORNIA, US pages 1529 - 1533 K.Y.ENG ET AL 'Optical FDM Switch Experiments With Tunable Fiber Fabry-Perot Filters' * page 1530, left column, paragraph 4 * * page 1530, right column, last paragraph - page 1531, left column, paragraph 1 * --- -/--	1-4,8,9	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H04B H04J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06 1993	GOUDELIS M.

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A	IEE PROCEEDINGS I. SOLID- STATE & ELECTRON DEVICES vol. 137, no. 6, December 1990, STEVENAGE GB pages 355 - 364 S.C.BATEMAN ET AL 'Adjustment of predetection filters in high-speed data transmission systems' * page 355, left column, last paragraph - right column, paragraph 1; figure 1 * -----	1-3,9	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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